Canadian Centre for Occupational Health and Safety

Centre canadien d'hygiène et de sécurité au travail

RADON IN BUILDINGS

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PREFACE

This publication provides basic information related to the possible hazards of radon and its decay products in buildings, and how they can be minimized. For a more comprehensive review, the reader may contact CCOHS or consult publications cited in the further reading list.

This publication was prepared as a source of information for health and safety committees and others interested in the possible health hazards posed by radon in buildings.

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1. INTRODUCTION

Radon gas is a product of the decay series that begins with uranium. Radon disintegrates spontaneously and produces alpha particles and solid, short-lived radioactive products, called radon daughters. These also disintegrate and produce more alpha particles.

Some amounts of radon and its daughters are present everywhere in the soil, water, and air. Particularly high levels occur in regions where soil or rock are rich in uranium. Radon is emitted by radium in the ground, groundwater and building materials. It can enter the indoor air where it and its decay products accumulate in poorly ventilated areas. Concentrations of radon and radon daughters are found in confined air spaces, such as basements and crawl spaces.

Radon daughters are inhaled with air and deposit in the lungs. The alpha particles the radon daughters emit increase the risk of lung cancer.

2. WHAT IS RADON?

Radon is an invisible, odourless, radioactive gas formed by the disintegration of radium. Radium is a decay product of uranium. Radon emits alpha particles and produces several solid radioactive products called radon daughters.

Each radioactive element decays at a unique rate described as the element's half-life. This is the time required for half the atoms of a radioactive substance to disintegrate. Radon's half-life is 3.8 days. This means that, in the absence of its parent radium, the intensity of alpha particles from a given sample of radon will diminish to half in 3.8 days, to half of the remainder in another 3.8 days, and so on.

Radon daughters have very short half-lives ranging from a fraction of a second to 27 minutes. As a result, radon daughters are present in significant quantities only as long as radon is present. If all the radon gas is removed, the radioactivity of radon daughters will fade away quickly.

The following figure illustrates the radioactive decay chain which produces radon and radon daughters.

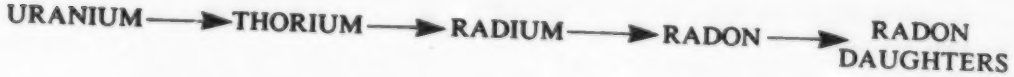

Figure - Production of radon and radon daughters from uranium

3. HOW DOES RADON ENTER BUILDINGS?

Radium in the soil directly under a building is normally the major source of indoor radon. Less important sources are radium in ground water and building materials.

Radium is produced by a decay of uranium (see Figure on previous page) and is a source of radon. The presence of uranium in soil and rock is an important indicator of places where radon can be present.

Because radon is a gas, a fraction of the radon produced in the soil can find its way into a building. The rest is trapped in the soil. There it decays to radon daughters which are solids, and much less able to move into the building air.

The concentration of radon in the air inside a building depends on the amount of radium present in the soil, and the ease with which the radon it produces can move through soil and building walls. Because radon is a gas, changes in the atmospheric pressure also affect its emission from the ground and its accumulation in the building air.

The concrete floor and walls in the basement slow down the movement of radon from the soil into the building. But cracks in the floor, wall slab joints, and the drainage system allow radon to enter a building.

Indoor radon concentrations are almost always higher than outdoor concentrations. Once inside a building, the radon cannot easily escape. The sealing of buildings to conserve energy reduces the intake of fresh air and worsens the situation. Radon levels are generally highest in cellars and basements because these areas are nearest to the source and are usually poorly ventilated.

4. WHAT ARE THE UNITS OF MEASURING RADON LEVELS?

The concentration of radon in the air is measured by its radioactivity in units of picocuries per litre (pCi/L) or becquerels per cubic meter (Bq/m^3). One Bq corresponds to one disintegration per second. One pCi/L is equivalent to 37 Bq/m^3.

The concentration of radon daughters is measured in units of working level (WL), which is a measure of the potential alpha particles energy per litre of air. One WL of radon daughters corresponds to approximately 200 pCi/L of radon in a typical indoor environment. But the relative concentration of radon and radon daughters may vary from one building to another. In the extreme case 1 WL corresponds to 100 pCi/L of radon. This situation is called full equilibrium and is extremely unlikely to occur. Cumulative exposure to radon daughters is expressed in working level months (WLM), where one working level month is equivalent to exposure at an average concentration of 1 WL for 170 hours.

Measurement data are reported in either of the above units. For making comparisons between the data from different sources, the following conversion chart may be useful:

1 pC/L	=	37 Bq/m^3		
1 m^3	=	1000 L		
0.01 WL	=	2 pCi/L	=	74 Bq/m^3
0.02 WL	=	150 Bq/m^3	=	4 pCi/L
0.1 WL	=	800 Bq/m^3	=	20 pCi/L

5. WHAT ARE ACCEPTABLE LEVELS OF INDOOR RADON?

In Canada, the Atomic Energy Control Board (AECB) sets radiation exposure limits. It gives two types of exposure limits--one for occupationally exposed persons and another for the general public. The annual occupational exposure limit is 4 WLM. The annual exposure limit for the general public is 0.4 WLM. There is no regulation regarding the acceptable maximum radon level in buildings and homes. In homes and other non-occupational settings, the maximum permissible annual average concentration of radon daughters caused by the operation of a nuclear facility is 0.02 WL (radon level 150 Bq/m^3). Health and Welfare Canada recommends 0.1 WL (radon level 800 Bq/m^3) as the action level and 0.02 WL (150 Bq/m^3) as the target level. The action level is what can be attained now. The target level is a longer term objective. Appendix A gives a summary of Canadian and other guidelines.

6. WHAT ARE THE HEALTH EFFECTS OF RADON?

The link between radon exposure and lung cancer is based on a study of lung cancer among uranium miners and other workers exposed to very high levels of radon daughters. There is no direct evidence linking radon exposure in buildings to an increased risk of lung cancer.

Radon is chemically unreactive. It does not react with body tissues. While some of the inhaled radon does dissolve in the body fluids, the resulting concentration is so low that the dose from the radon itself is negligible.

Radon daughters become attached to tiny dust particles in the indoor air. When these particles are inhaled, a fraction is deposited in the lungs. There the radon daughters disintegrate and the released alpha particles penetrate nearby lung tissue. Since alpha particles cannot penetrate more than a fraction of a millimeter into the tissue, the damage is confined to the lung tissue in the immediate area.

Radon daughters also emit some low intensity beta and gamma rays which travel farther through the lung tissue. Because beta and gamma rays are absorbed over a large lung volume, their harmful effects are thought to be minimal.

People exposed to high radon levels have an increased risk of developing lung cancer. The extent of risk depends on the radon concentration in the air and the duration of exposure. The Committee on the Biological Effects of Ionizing Radiation (BEIR, IV, 1988) has estimated lifetime risk of 350 extra lung cancer cases if one million people are exposed to 1 WLM of radon daughters.

Smoking increases the risk of lung cancer. Smokers exposed to radon daughters are at even greater risk of developing lung cancer.

7. WHAT DO WE KNOW ABOUT INDOOR RADON LEVELS?

Little information exists on radon levels in Canadian buildings. One collection of Canadian indoor radon measurements, published in 1980, was the result of a cross-country study of radon in private homes. The study showed that in a small fraction of houses, the radon daughter concentration exceeded 0.02 WL. The following table, which summarizes the results, shows that levels varied from one geographic area to another and even from house to house. In general, the study showed higher levels of radon where ventilation rates were low. A study performed in the United Kingdom showed varying degrees of elevated radon levels in offices and similar workplaces located in areas where radon levels were high in homes.

Table - Homes with radon daughter concentration 0.02 WL and above

Location	Percentage of homes
Calgary, Alberta	0.8
Charlottetown, Prince Edward Island	1.2
Fredericton, New Brunswick	6.6
Halifax, Nova Scotia	9.3
Montreal, Quebec	2.2
Quebec City, Quebec	3.1
Saint John, New Brunswick	4.2
Sherbrooke, Quebec	8.2
St John's, Newfoundland	2.1
St Lawrence, Newfoundland	6.0
Sudbury, Ontario	11.3
Thunder Bay, Ontario	3.3
Toronto, Ontario	1.7
Vancouver, British Columbia	0

Source: McGregor, R.G. Background concentrations of radon daughters in Canadian homes. Health Physics. Vol. 39 (Aug. 1980) p. 285-289.

Canadians concerned about possible radon daughter exposure should contact one of the agencies listed in Appendix B.

8. HOW ARE RADON LEVELS DETECTED?

Indoor radon level is measured by air sampling and by alpha dosimetry using radon track etch dosimeters. A number of companies manufacture and sell measuring instruments.

Air Sampling Techniques

- Air samples are collected at specified locations. They are brought back to the laboratory to measure the radiation produced in one litre of air. This method reflects an instantaneous point concentration. It does not give a true average concentration for places where radon levels vary from one day to another or during a day.

- A canister containing activated charcoal is exposed to air at the sampling location for a few days. Activated charcoal absorbs radon gas from the air. The sample is brought back to the laboratory to measure the amount of radioactivity absorbed. This inexpensive method gives an average radon level for the period during which the sampler was exposed to the air.

- An electronic instrument, called a working level monitor, is taken to the measurement site. Working level meters give readings immediately. They are best suited for evaluating the effectiveness of control methods for reducing indoor radon levels.

Alpha Dosimetry

A radon track etch dosimeter is the cheapest long-term monitoring device for alpha radiation from radon gas and radon daughters. The dosimeter contains a piece of plastic inside a small box. When alpha particles strike the plastic, they leave behind damage tracks. The intensity is measured by counting these tracks. Track etch dosimeters are simple to use. They give an average exposure for the duration of the exposure, which can range from several days to months.

9. WHAT ACTIONS CAN BE TAKEN TO REDUCE INDOOR RADON LEVELS?

Reducing the emission from the ground into the building and increasing the ventilation in basements and other areas where radon accumulates, are the usual means of reducing indoor radon levels.

Caulking and sealing cracks and holes in basement floors and walls helps stop the release of radon from the ground into the building. Painting basement floors and wall surfaces also helps. Epoxy paints are the most effective in reducing radon emission. Typically, two or more coats of paint, or paint used with a sealant compound, are needed to adequately seal pores. Polyethylene sheets serve as a good barrier to radon emission. In cases

where high radon levels are present because uranium mill tailing was used as landfill, it may be necessary to replace the fill. Alternatively, it may be possible to reduce radon concentration to an acceptable level by coating the surface of the building foundation. Covering walls with gypsum, plaster or wallpaper does not reduce radon emission.

Since proper surface treatment reduces the emission of radon, the radon concentration increases inside bricks, slabs, floors and unpainted areas. Driving nails and hooks into the treated wall increases radon emission.

Air filtration can decrease the radon daughter concentration as much as 90 percent. The majority of radon daughters are attached to airborne particles in the building. Particle removal by air filtration helps decrease radon daughter concentration in the air.

Increasing ventilation reduces indoor radon levels. Opening a window can help dramatically. The radon level is lower when the inside air is allowed to escape and fresh air can enter the building.

10. SUMMARY

Radon, a radioactive gas formed by the decay of radium, can be present in buildings. It enters from the soil through tiny cracks in basement floors and walls. Radioactive decay of radon produces solid radioactive particles called radon daughters. Exposure to alpha particles produced by the radioactive decay of high concentrations of radon and radon daughters increases the risk of lung cancer.

Aside from the nuclear and mining industries, there is relatively little information on indoor radon levels in Canada. But surveys of radon levels in private homes show that there are areas of the country where radon concentrations in basements reach levels high enough to be of concern. In these areas, there may be poorly ventilated basement workplaces where radon accumulation might also be high.

Indoor radon levels can be reduced by caulking and sealing the basement and by opening windows to let in fresh air. In some situations more sophisticated ventilation systems may be needed.

APPENDIX A

Criteria for Indoor Radon and Radon Daughter Levels

(Based on a compilation by Radiation Protection Service, Ontario Ministry of Labour.)

Canada		
▪ AECB[1]	0.15 WL	Prompt action
	0.02 WL	Primary criterion
	0.01 WL	Investigation level
▪ Ontario[2]	0.02 WL	Design criterion
▪ Canada[3]	800 Bq/m^3 (0.10 WL)	Action level
	150 Bq/m^3 (0.02 WL)	Target level
U.S.A.		
▪ Houses built on or near Uranium	must be less than 110 Bq/m^3 (3 pCi/L or approximately 0.015 WL)	
▪ Phosphate mining regions in Florida	greater than 7400 Bq/m^3 (200 pCi/L or approximately 1.0 WL)	Immediate remediation
	740 - 7400 Bq/m^3 (20 - 200 pCi/L or approximately 0.1 to 1.0 WL)	Remediation within a few months
	150 - 740 Bq/m^3 (4 - 20 pCi/L or approximately 0.02 to 0.10 WL)	Remediation within a few years
	150 Bq/m^3 (less than 4 pCi/L or approximately 0.02 WL)	Reduce as low as feasible
▪ Environmental[4] Protection Agency	150 Bq/m^3 (4 pCi/L or approximately 0.02 WL)	

All levels do not include background concentration, currently reported to be approximately 0.004 WL.

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1. For radioactive clean-up at Port Hope and pre-'77 houses in Elliot Lake and Bancroft.
2. Ontario Building Code Bylaw for new buildings in uranium mining communities.
3. Guideline suggested by Federal/Provincial Advisory Committee on Environmental and Occupational Health.
4. 1987 guideline for radon in homes due to natural radiation sources.

Sweden

	Permitted maximum levels
▪ Existing buildings	400 Bq/m^3 (approximately 0.11 WL)*
▪ Remodelled or renovated houses	200 Bq/m^3 (approximately 0.054 WL)*
▪ New houses	70 Bq/m^3 (approximately 0.02 WL)*

USSR

No criteria for radon in air in houses. Only criteria for radioactivity in building materials.

International Commission on Radiological Protection (ICRP)

	Recommended levels
▪ Existing houses	less than 200 Bq/m^3 (0.054 WL)*
▪ New buildings	design criterion, less than 100 Bq/m^3 (0.027 WL)*

World Health Organization (WHO)

	Recommended levels
▪ Existing buildings (Remediation before an additional 27 WLM accumulated i.e. within a few years)	0.11 WL

* 1 WL is taken to correspond to 100 pCi/L of radon concentration in the air.

APPENDIX B

Government Agencies to be Contacted in Case of Suspected High Indoor Radon Daughter Levels

Federal

Radiation and Medical Protection Bureau
Environmental Health Directorate
Health and Welfare Canada
Brookfield Road Confederation Heights
Ottawa Ontario K1A 1C1
(613) 954-6647

British Columbia

Radiation Protection Service
Ministry of Health
200 - 307 West Broadway
Vancouver British Columbia
V5Y 1P9
(604) 660-6630

Alberta

Radiation Health Service
Alberta Occupational Health and Safety
10709 Jasper Avenue
Edmonton Alberta T5J 3N3
(403) 427-2691

Saskatchewan

Mines Pollution Control Branch
Department of the Environment and Public Safety
PO Box 3003
Prince Albert Saskatchewan
S6V 4V1
(306) 953-2224

Manitoba

Manitoba Cancer Treatment and Research Foundation
100 Olivia Street
Winnipeg Manitoba
R3E 0V9
(204) 787-2197

Ontario

Radiation Protection Service
Ontario Ministry of Labour
81 Resources Road
Toronto Ontario M9P 3T1
(416) 235-5922

Quebec

Ministère de l'Environnement
3900, rue Marly
Ste-Foy Québec G1X 4E4
(418) 643-6071

New Brunswick

Department of Health and Community Services
Carleton Place
P O Box 5100
Fredericton New Brunswick
E3B 5G8
(506) 453-2536

Nova Scotia

Department of Health
1690 Hollis Street
Joseph Howe Bldg
P O Box 488
Halifax Nova Scotia B3J 2R8
(902) 424-4391

Prince Edward Island

Department of Health and Social Services
Sullivan Bldg
16 Fitzroy Street
P O Box 2000
Charlottetown Prince Edward Island
C1A 7N8
(902) 368-4900

Newfoundland

Occupational Health and Safety Division
Department of Labour
Confederation Bldg West
P O Box 4750
St John's Newfoundland
A1C 5T7
(709) 576-2729

Yukon

Consumer, Corporate and Labour Affairs
Department of Justice
P O Box 2703
Whitehorse Yukon
Y1A 2C6
(403) 667-5256

Northwest Territories

Safety Division
Department of Justice
P O Box 1320
Yellowknife NWT
X1A 2L9
(403) 873-7996

FURTHER READING

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Guidance for dealing with radon. Environmental Protection Agency Journal. Vol. 12, no. 6 (1986) p. 12-13.